

LIGHT WEIGHT ESCAPE CAPSULE FOR FIGHTER AIRCRAFT

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ABSTRACT

Emergency crew escape capabilities have been less than adequate for fighter aircraft since before WW II. From the over-the-side bailout of those days through the current ejection seat with a rocket catapult, escaping from a disabled aircraft has been risky at best. Current efforts are underway toward developing a high-tech, "smart" ejection seat that will give fighter pilots more room to live in the sky but, an escape capsule is needed to meet current and future fighter envelopes. Escape capsules have a bad reputation due to past examples of high weight, poor performance and great complexity. However, the advantages available demand that a capsule be developed. This capsule concept will minimize the inherent disadvantages and incorporate the benefits while integrating all aspects of crew station design. The resulting design is appropriate for a crew station of the year 2010 and includes improved combat acceleration protection, chemical or biological combat capability, improved aircraft to escape system interaction, and the highest level of escape performance achievable. The capsule is compact, which can allow a reduced aircraft size and weighs only 1200 lb. The escape system weight penalty is only 120 lb higher than that for the next ejection seat and the capsule has a corresponding increase in performance.

BACKGROUND

Emergency crew escape capabilities have been less than adequate for fighter aircraft since before WWII, when over-the-side bailout was the only means of escape. The development of jet aircraft was accompanied by ejection seats that were catapulted from the cockpit. This was followed by the addition of a rocket for tail clearance and runway ejections and then a drogue parachute for stabilization and deceleration at high speeds. The current USAF ejection seat, the ACES II, includes a small gimbaled rocket that helps stabilize the escape system and airspeed sensors to vary parachute sequencing. From 1957 to 1984, the rate of major injury or fatality (M/F rate) for non-combat ejections with sufficient altitude above the ground was an average of 26 percent. The ACES II seat shows significant improvement with a M/F rate of 14 percent. When

this data is filtered to isolate the effect of airspeed, the results are very interesting. In fact, only 10 percent of the non-combat ejections were over 400 KEAS (knots equivalent airspeed, 687 psf dynamic pressure). Data from combat missions in Vietnam showed that ejection speed increased dramatically, with approximately 50 percent of ejections occurring at over 400 KEAS. Due to a limited amount of combat data, the non-combat data with known airspeed and cause of injury was used for judging injury rates. The M/F rate for ejections under 400 KEAS became 23 percent and over 400 KEAS was 65 percent. (The corresponding ACES II M/F rates are 9 percent and 70 percent.) Based on these rates, the combat ejection M/F rate could exceed 45 percent due to airspeed. Technology is currently available for the development of a controllable ejection seat under the Crew Escape Technologies (CREST) program. This program will demonstrate an escape system that can remain stable at speeds up to 700 KEAS (1660 psf) and steer away from the ground during low altitude ejections. An ejection seat based on the CREST program results will improve low altitude escape performance and provide greater protection at high speed. However, it will be difficult for an open ejection seat to meet the 700 KEAS goal while fighter aircraft can already fly at 800 KEAS (2100 psf) or more. The desire for further improvements in safe escape led to an effort to develop an escape capsule that could take advantage of current and emerging technology and perhaps become available early in the next century.

Escape capsules provide protection from the elements and are a natural solution to the high-speed escape problem. However, previous capsule experiences in the USAF have led to a generally bad reputation for capsule escape systems. The two operational capsules that have been flown (the F-111 and the B-1A, the B-1B has ejection seats) were based on technologies that are 20 years old or more (Figure 1). This lack of technological capability led to designs that were heavy and difficult to make feasible. The F-111 capsule now weighs 3,300 lb (crew of two), includes a large portion of the forward fuselage and contains many heavy instruments and controls. The B-1 capsule weighed nearly 10,000 lb (crew of 6) which resulted in a similar weight per crew member to that of the F-111 (about 1,700 lb). In contrast, an ejection seat with the capabilities sought by the

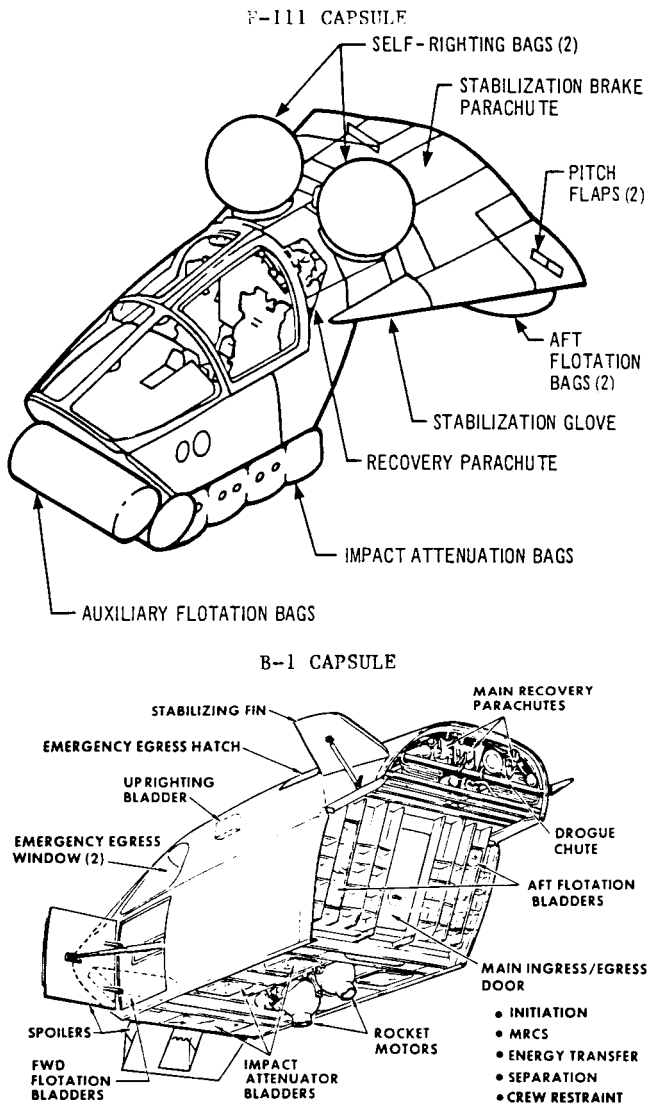


Figure 1. F-111 and B-1 Capsules

CREST demonstrator escape system is expected to weigh from 600 to 700 lb for one person when ejected. The comparatively higher weight of capsules leads to greater penalty to the aircraft and, because of aircraft weight limitations imposed, it is difficult to achieve the same performance levels as those possible for an ejection seat. The capsule weights are high for a number of reasons. The underlying reason is that the escape system designs were constrained by predetermined fuselage structural designs and crew stations. This led to excess volume in the capsules which allowed capsule weight increases caused by other aircraft systems. This approach also precluded the use of an insertable capsule which would reduce the amount of aircraft structure carried in the capsule and allow a minimum volume for the capsule. Lack of today's technologies prevented solutions to the problem of crew station/capsule weight as well. The older crew stations were full of control panels with their associated boxes, control units, computers and

countless wires. These combined weights added to the total that the escape rocket system had to accelerate. In addition, relatively dumb rockets and control systems were used that lacked efficiency and generally ended up undersized due to weight growth of the capsules. Another problem with the previous capsules was the method of landing them after an ejection. The most efficient approach at the time was to use inflatable airbags to absorb landing impact during parachute descent. This approach has a limited performance envelope which has led to a 15 - 20 percent major injury rate due to landing impact for the F-111. A factor that added to the weight problem and created maintenance difficulties was that the F-111 and B-1 capsules were integral to their aircraft fuselage and used explosive shaped charges as the means of separating for ejection. This meant that all capsule subsystems were accessible only through the skin on the fuselage. Periodic refurbishment of the capsule involved removing much of the skin and replacing all pyrotechnic components. This scarred past for escape capsules has severely limited investment toward future capsule escape systems.

Two other areas of concern are G-induced loss of consciousness and ingress and egress in a chemically or biologically contaminated (CB) environment. Today's fighter aircraft are designed to be able to turn at 9 G while fighter pilots can only withstand 7 to 9 G through intensive physical efforts. Also, these aircraft are capable of reaching acceleration levels of 9 G faster than pilots' bodies can compensate for them. This situation has led to 7 deaths of Air Force pilots directly attributed to G loss of consciousness since 1983. Finally, there is no current method for ingressing or egressing the cockpit in a CB environment while keeping the cockpit "clean". Efforts are underway to develop ways to keep the environmental control system air free of contamination through the use of catalytic converters or a closed loop system, but the pilot must be allowed in and out of the crew station. The current approach uses a dirty cockpit and the pilot must wear cumbersome, hot protective gear while flying the mission.

DISCUSSION

The Air Force Wright Aeronautical Laboratories, Aircrew Protection Branch has engineered an approach to providing capsule escape over the last four years with encouraging results. The solution involves integration of capsule, crew station, airframe, and crew member requirements and emphasizes the need for an independent crew station and escape system design group whose requirements must be included in future aircraft development programs. The program focused on providing high speed escape capability with maximum escape system performance, protection from aircraft combat accelerations and ingress and egress in a CB environment.

The escape capsule design that emerged from our effort known as Concept Development of a Canopy Escape Module was based on the F-16 geometry as shown in Figure 2. The F-16 has a large, single-piece transparency that is convenient for attaching a crew station to form a capsule. Also, there

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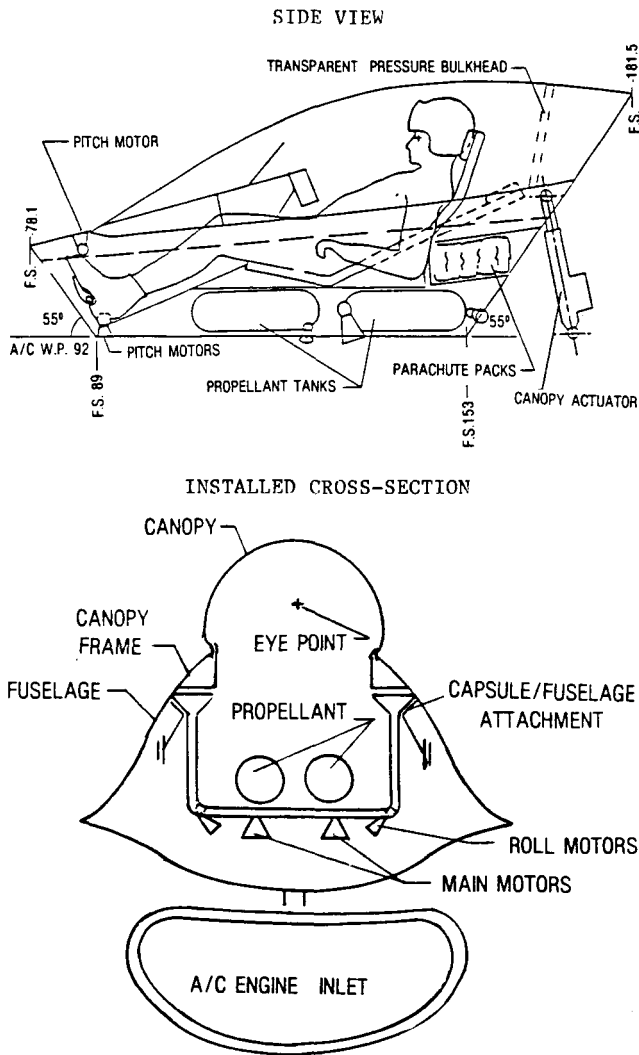


Figure 2. Canopy Escape Module

was recent data available on the F-16 and a prototype F-16 aircraft was at our disposal. The effort focused on providing safe escape capability up to a maximum 950 KEAS and the best combat acceleration (G) protection possible. The design really began with the G protection issue in order to define the pilot position. A capsule and escape subsystems were put around the pilot and fitted within the F-16 fuselage. This left a certain volume for the crew station which was less than optimum. The width of the F-16 at the crew station does not allow much room beside a reclined pilot. In the ideal case, the crew station requirements would have the opportunity to drive fuselage design. Following crew station design, aircraft to capsule interfaces were addressed and methods of ingress and egress in a CB environment proposed.

Reclined Seat & Minimum Weight Capsule

The approach to G protection was to recline the seat to reduce the column of blood between the head and heart. A 65 degree reclined seat was

designed that could provide protection up to 9 to 12 G without requiring the pilot to perform strenuous anti-G exercises while trying to fight the enemy. (See Figure 3 below.)

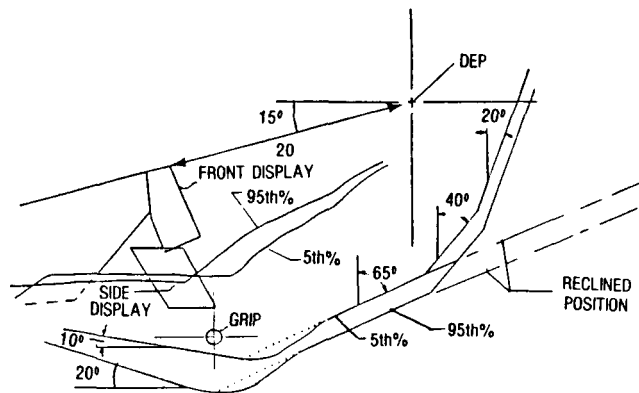


Figure 3. Reclined Seat Design with 5th and 95th Percentile USAF Male Pilot Outlines

Having a reclined seat helped reduce capsule weight by minimizing the cross-sectional area. This lowered the propulsion weight requirements by reducing capsule aerodynamic drag. The capsule was made insertable into the airframe to avoid having to accelerate aircraft fuselage structures during ejection. The body of the capsule was designed to be made of composite materials and molded around the minimum volume required for the crew station. The weight of the crew station was minimized by taking advantage of predicted technologies for the year 2010. The head-up display would be projected from the helmet, and voice control, eye tracking and artificial intelligence would be used to minimize the number of instruments and controls required. The front displays would be flat panel type to eliminate all CRTs from the crew station. Finally, all display generators, control units, radios, and other avionics would be outside the capsule with data transfer through fiber optics or coaxial cable. As a result the only weights required for the capsule are structure, escape systems, display and control input devices, and the crewmember. The resulting capsule weight to meet today's aircraft performance of 800 KEAS is just over 1200 lb and the associated weight penalty to the aircraft only increased by 27 percent (117 lb) over that estimated for an ejection seat based on the CREST technologies.

Escape System Design & Performance

This Canopy Escape Module (CEM) design was able to incorporate the same controller technologies being developed for the CREST demonstrator and added a highly controllable propulsion system. The propulsion system uses gel propellants which consist of thickened liquid oxidizer and fuel. These materials ignite instantly when they meet which eliminates the need for igniters and allows pulsing of the propellant for a very simple but effective throttling method. These propellants are highly efficient and can be used more efficiently compared to solid propellants which cannot

be started and stopped at will. The propulsion system was sized by estimating the amount of propellant required to bring the capsule to a stop from a maximum speed dive at sea level and comparing the results to the propellant required to recover the capsule at maximum velocity at Mach 3.5. It was estimated that a 950 KEAS capable capsule with 190 lb of propellant could recover the capsule with only one second remaining to impact in a 950 KEAS vertical dive. The high altitude case for a 950 KEAS capsule (42,000 ft) requires large amounts of propellant due to the high velocity of 3400 ft/s (compared to 1600 ft/s at sea level). It takes far longer to slow down from such a high speed, but the 190 lb of propellant was found to be adequate since the accelerations could be much lower. By having a gel propulsion system and adding an appropriate ground sensor, it was possible to add a retrorocket landing capability. The same propulsion system used for ejection would be reused to bring the capsule to a stop on the ground regardless of wind and slope conditions. This landing method can be achieved at a lower weight than airbags and can reduce the landing injury rate dramatically.

Crew Station Design & Considerations

The CEM crew station that resulted from reclining the pilot into a low-profile capsule led to some potential problems. The total surface area available for controls and instruments is only half of that for our current fighters. In addition, the reachable and visible area in flight is less than one-fourth of that currently available. Part of this severe limitation was caused by the F-16 fuselage and bubble canopy geometries. Some increase in side panel area can be expected in future fighter aircraft. However, the available space will still be very limited due to the reclined position of the pilot. This will require a tremendous change in crew station design and the overall pilot vehicle interface. To accomplish the necessary changes, the aircraft will have to have a pilot's associate to automate many of the functions currently being performed by the pilot. The best solution involves the use of the Super Cockpit as proposed by the Human Systems Division which would have the helmet project a complete computer enhanced world through the pilot's visor. This computer world would be overlaid on the real world to highlight threats, course information, targets, and assist the pilot's orientation. This super cockpit would also have an audio system that could cue the pilot in three dimensions by having threats and other things announce themselves to the pilot from specific directions. When combined with voice control, the pilot's ability to tell the aircraft systems what to do, these technologies would eliminate the current dependence on control surface area and a multitude of knobs and switches. Another effect of reclining the pilot is to make it more difficult to search the space around the aircraft for threats. This is most difficult in the rearward direction where much of the danger is coming from. Pilots currently whip their heads around to compare their attitude with the attitude of their enemy. Preventing them or making it difficult for them to do this would make this system impossible to achieve unless there is an

even better approach. Our efforts have led to a proposal that the pilot could take advantage of Super Cockpit system capabilities to allow the pilot to perform combat maneuvers while looking in the forward direction. The three dimensional audio capability would cue the pilot to the enemy's location and the helmet display would project a rearview mirror image at a location 180 degrees from the direction of the sound (and the enemy). This image would show the orientation of the enemy aircraft and would provide a consistent reference for the pilot to act on. The pilot could then maintain his own head and body attitude relative to his aircraft and would have easier access to the other information needed to maintain maximum aircraft performance. The pilot would stay in the best position for G protection and would be better able to maintain concentration and awareness during combat maneuvers.

Capsule/Aircraft Interfaces & CB Ingress/Egress

The fact that the capsule was designed to be insertable led to several benefits. The capsule and its volume became independent of other aircraft changes to a large extent. This way when fuselage weight increases in the nose, the capsule weight doesn't increase by default. Also, by being inserted into the fuselage, the capsule could be removed for maintenance of both the capsule and the fuselage components surrounding it. In order to accomplish this, some kind of latching mechanism would be required between the capsule and the airframe. There would also have to be a releasable interface between the two structures for power, data transfer, and environmental control system air. This removability of the capsule has the potential to provide a CB ingress and egress mechanism. The pilot could be left in the cockpit while it is removed and replaced by another pilot and cockpit. This would allow aircraft turnaround along with time for careful decontamination of returning capsules. Another approach for CB ingress and egress was proposed with less dependence on technology and support equipment. A plastic curtain could be deployed around the open crew station between the canopy and the canopy sill. This curtain would have a special zipper on it matching a zipper on a large impermeable suit. When these zippers are mated an airlock is created between the suit and the canopy (or shelter). This entire system might last several uses before being disposed of and replaced. (See Figure 4.)

CONCLUSIONS

Previous escape capsule experiences in the USAF have led to a reluctance to pursue such escape systems for future fighter aircraft. Our efforts have shown that emerging technologies will allow a capsule to be developed that offers the maximum escape system performance at a small increase in weight penalty to the aircraft. New technologies are available which allow safe escape over a larger portion of the aircraft flight envelope and can greatly reduce landing impact injuries. A concerted and integrated crew station and escape system design can lead to greatly improved pilot performance by providing increased G protection

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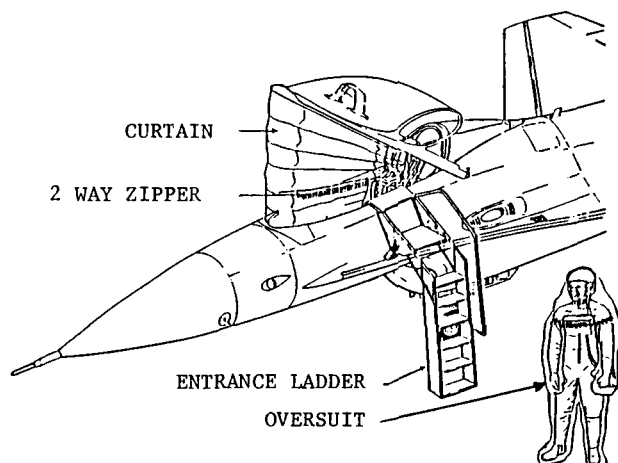


Figure 4. Proposed CB Protection System

and advanced crew station technologies. The CEM has been designed to achieve these improvements while reducing maintenance problems by having a removable capsule. The serious problem of ingress and egress in a CB environment can be overcome by using the removable capsule as a transfer means. Another approach has been proposed involving a plastic curtain around the open cockpit and a large plastic suit that can be zipped to the curtain forming an airlock.

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